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Low-cost High Data-rate Direct-Conversion Multi-port Receiver for Millimeter-wave Indoor Wireless Applications

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Abstract

Performance analysis of a millimeter-wave direct conversion receiver, based on the S-parameter measurement results of recently fabricated multiport circuit, is presented in this paper. In order to obtain realistic and highly accurate modeling, the measured S-parameters of the fabricated multiport are introduced in computer model using the schematic platform of Keysight's Advanced Design System (ADS). The performances in terms of Bit Error Rate (BER) are analyzed for various data-rates of a pseudorandom QPSK signal: 100 Mbps, 200 Mbps, 500 Mbps, 800 Mbps and 1 Gbps. The obtained BER results, demonstrate the effectiveness of the direct QPSK multiport demodulator for high data-rates up to 1 Gbps.

1. Introduction

The 7-GHz unlicensed frequency band around 60 GHz has recently been identified as a potential band for high data rate wireless communications (several Gbit/s). One of its principal properties is high signal attenuation due to the oxygen absorption and obstacles, resulting in transmission range limitation. However, it will enable a high level of frequency re-use factor, making it attractive for several short-range wireless applications [1, 2].

Apart from the above-mentioned issues, the hardware implementations of high performance radio frequency (RF) transmitter/receiver modules are very challenging to achieve at 60 GHz band. This is due to many factors, including, non-linearity of power amplifiers, oscillator phase noises, and DC offset phenomenon. All of these factors have more influence on the circuits designed at the millimeter band than those designed at lower frequencies [3].

In order to deal with these problems, several alternatives were explored in recent years, amongst others, the very promising multiport technique. The latter offers a straightforward approach for broadband operations, low-power consumption, and low manufacturing costs, making it an appropriate choice for various indoor millimeter-wave wireless applications [4, 5].

In this paper, direct conversion quadrature demodulator analysis based on the S-parameter measurements of a recently fabricated 60 GHz multiport circuit is presented. The computer model of the proposed demodulator is performed using Keysight's Advanced Design System (ADS) software due to its highly accurate modeling capability. In order to assess the performances of the proposed structure, Bit Error Rate (BER) results for various data-rates (100 Mbps, 200 Mbps, 500 Mbps, 800 Mbps and 1 Gbps) of pseudorandom QPSK signal are presented and discussed.

2. Multiport circuit design

The multiport circuit in Figure 1(a), has been designed to operate at 60 GHz band, and has been fabricated on a very thin ceramic substrate (ε_r = 9.9 and h = 127 μm) in Miniature Hybrid Microwave Integrated Circuit (MHMIC) technology. In order to ensure an accurate measurement, the on-wafer Through Reflect Line (TRL) calibration technique has been adopted using the calibration kit on the same ceramic substrate, as shown at Figure 1(b) [4], [6].

The measurements were carried out using a Cascade Microtech probe station (equipped with GSG 150 μm coplanar probes) connected to millimeter-wave network analyzer (E8362B) from Keysight (Agilent) Technologies, with E-band extension modules, operating in 60 – 90 GHz band. Figure 1(c) shows a detail of the on-wafer S-parameter measurement set-up of thed V-band multiport circuit. A coplanar line (CPWG) to microstrip transition is designed and fabricated to enable measurements with GSG 150 μm coplanar probes [4, 5].

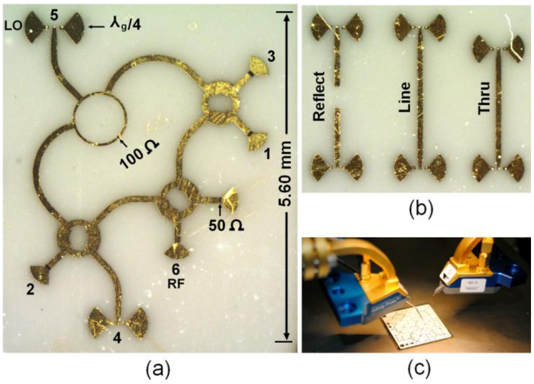

Figure 1. Photograph of (a) The fabricated prototype of multiport (six-port) circuit, (b) TRL calibration standards, and (c) On-wafer S-

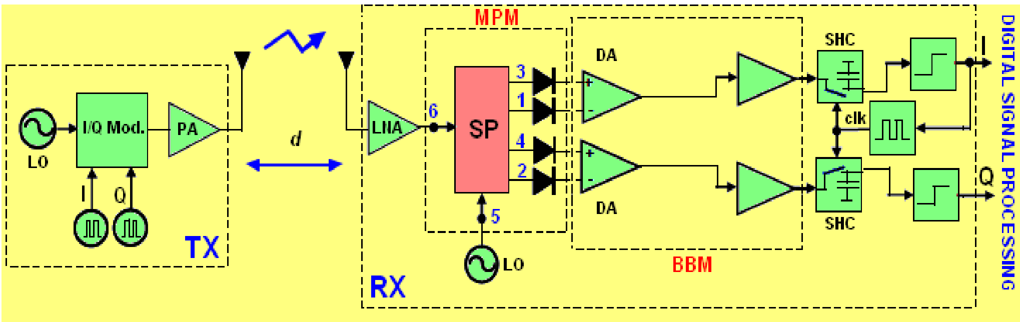

Figure 2. The block diagram of the wireless link using the multiport (six-port) direct conversion quadrature receiver.

3. 60-GHz Multiport Demodulator Model

Figure 2 above shows simulation block diagram including more details on the multiport (six-port) homodyne receiver architecture. For a realistic simulation model, the S-parameter measurements of the fabricated 60 GHz multiport circuit in Figure 1(a), has been implemented in the multi-port model (MPM) of Figure 2, using the schematic platform of Keysight's Advanced Design System (ADS) software [6]. The complete receiver model is composed of a passive broadband multi-port circuit, four wideband power detectors (1 to 4), and the baseband module. Basically, the principle of operation is as follows: the multiport output signals are linear phase shifted combinations of reference local oscillator (LO) at port 5 and of input unknown RF modulated signals port 6; the baseband quadrature signals are obtained by using a pair of high-speed differential amplifiers (DA) fed by the four output detected signals [7]. Sample and hold circuits (SHC) operated at the symbol rate (clk) and high-speed comparators are used to improve the quadrature signals waveform at the receiver output for the QPSK modulation scheme. This computer model demonstrates that a direct high data rate QPSK demodulator could be successfully employed through using low-cost millimeter wave multiport technology.

The plot of the q_i points based on S-parameter measurements of the proposed multiport circuits is shown in Figure 3.

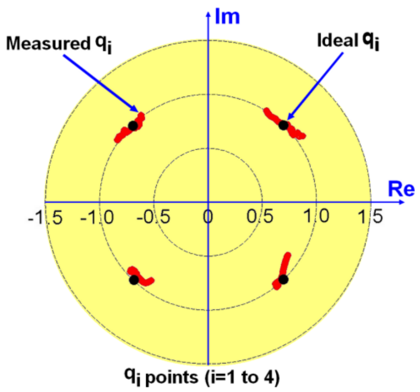

Figure 3. The q_i points for 10% of bandwidth of the fabricated six-port circuit.

As can be observed, the q_i points are placed equidistantly from the origin and angularly spaced by 360º divided their number (i = 4 in this case) [8]. These results highlight the performance of the proposed six-port circuits, and demonstrate a high accuracy location of the q_i points over the considered 60 GHz frequency band. Therefore, the magnitudes of the q_i points are equals and closer to 1, while the argument difference is closer to 90º between two corresponding q_i points.

4. BER Performance Analysis

The BER (Bit Error Rate) is the most relevant parameter to analyze the quality of wireless communication links. Figure 4 shows the BER results of various QPSK demodulation rates (100, 200, 500, 800, and 1000 Mbit/s), using the computer model in Figure 2. As can be observed, for a BER of 10^{-6}, the ratio E_b/N_0 varies of only 2.2 dB for transmission rates ranging from 100 Mbits/s to 1 GBits / s. However, this difference is about 2.8 dB for a BER of 10^{-9}.

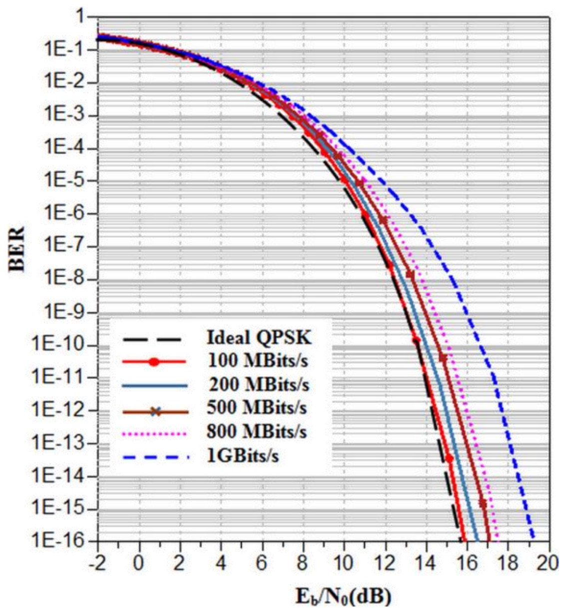

Figure 4. Bit error rate of QPSK six-port demodulator at 60 GHz for different data- rates: 100 Mbps, 200 Mbps, 500 Mbps, 800 Mbps and 1 Gbps.

The difference between the ideal curve and the 1 Gbps curve is around 3 dB at 10^{-12} BER value, which is acceptable even for the use for very sensitive applications as uncoded wireless HD [8].

5. Acknowledgements

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6. References

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